


XVI ERIAC
DECIMOSEXTO ENCUENTRO
REGIONAL IBEROAMERICANO DE CIGRÉ

17 al 21 de mayo de 2015




A1-16

Comité de Estudio A1 - Máquinas Eléctricas Rotativas

# DEVELOPMENT OF NEW FORMALDEHYDE-FREE STATOR CORE LAMINATION

**Thomas Hildinger***
**Voith Hydro Holding GmbH**
**Brazil**

**Axel Kratzsch**
**Voith Hydro Holding GmbH**
**Germany**

***Summary*** *– Health problems due to the appearance of significant formaldehyde concentrations in generator rooms are a relatively new phenomenon in the hydro power business and were reported in 2006 for the first time. Subsequent investigations revealed the release of formaldehyde from the stator core lamination to be the root cause of this problem. The phenomenon was found to be present within the whole large hydro power business, regardless of the competitive situation, as the varnish commonly used belongs to the same class of materials. Besides short term activities to reduce formaldehyde emissions, some efforts have been necessary to convince varnish manufacturers, steel producers and punching shops to go for new varnish developments, based on a novel class of materials. The challenge was to achieve the required mechanical and electrical product characteristics and simultaneously assure a sufficient processability on various varnish lines. This paper describes some studies which were made along the production chain and shows the current status of the situation.*

***Keywords:*** Formaldehyde – Generator – Emissions – Stator – Insulation

## 1 INTRODUCTION

The first reference to complications caused by formaldehyde emissions in the generator room can be found in a report which was issued in 2006 and dealt with the pumped storage hydro power station Waldeck 2 (Germany) [1]. These emissions were observed after the stator core had been replaced during a modernization of the machine. Shortly after having entered the generator room, staff members complained of watering eyes and respiratory troubles. Measurements were then taken which showed a high concentration of free formaldehyde in the ambient air. The cause of the formaldehyde contents was found to be the sheet insulation (varnish) of the stator core. Investigations in other power stations confirmed these findings. This problem is of a large-scale nature, a fact which revealed itself quickly, because the C6 insulating varnishes that are used in the market for pre- and post-varnishing of the stator core sheets are usually based on melamine or phenolic resins. The chemism of these substances cause the emission of formaldehyde while and after the varnish is cured.

Soon it became obvious that remedial measures had to be taken, even though there are no standardized cross-national occupational exposure limits. Free formaldehyde is considered to be harmful to the human body and was classified as carcinogenic by the IARC (International Agency for Research on Cancer) in 2004.

* Thomas.Hildinger@Voith.com

As a first remedy, the access to generator rooms which had an increased concentration of formaldehyde in the ambient air was restricted; in addition, personal protective equipment was adapted, for example, supplemented with breathing masks.

Measures to reduce formaldehyde concentrations that were intended to take effect quickly were tried subsequently. For example, such measures included continuous cleaning of the ambient air by means of filter systems. Another point of focus was to optimize the curing process while varnishing the stator cores as well as subsequent thermal treatment.

## 2 MEASUREMENT METHOD USED FOR DETERMINING FORMALDEHYDE CONTENT

The method of measuring formaldehyde emissions in laminated steel sheets was defined according to VDA Directive 275 (Formaldehyde release by modified flask / UV Vis Spec method, 1994) [2]. A sheet coated on both sides and being 40 mm x 100 mm in size is mounted in a closed container above distilled water and stored for a defined time period at constant temperature. After the container has cooled down, the quantity of formaldehyde dissolved in the distilled water is analyzed in relation to the coated surface using spectrophotometry.




Fig. 1. Test setup for determining formaldehyde emissions from varnished sheet samples according to VDA Directive 275 [2]

## 3 MEASURES TO REDUCE FORMALDEHYDE EMISSION IN CONVENTIONAL VARNISHING SYSTEMS

Full-scale tests showed that the concentration of formaldehyde emission can be reduced by extending the curing process in the furnace. A post treatment of the sheet packages at increased temperature also turned out to have an emission reducing effect. In most cases, the more viable solution was to increase the furnace retention time even though this considerably increases production times. The different methods used and their results are presented below.

### 3.1 Effect of furnace retention time during application

A production facility was subjected to tests and the effect of the furnace retention time during post-varnishing was determined. Figure 2 shows the effect of the curing time that was extended from 40 sec to 120 sec for three different C6 varnishing systems on formaldehyde emission. As can be clearly seen,

formaldehyde concentration was reduced from originally about 100 to 180 mg/m² down to values of less than 20 mg/m².

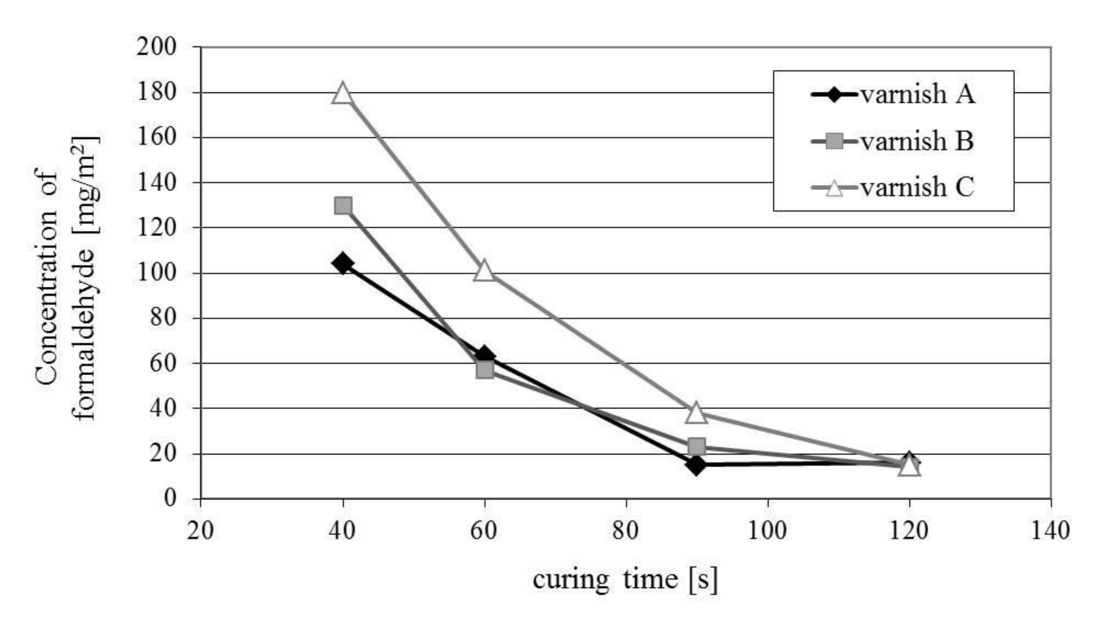



Fig. 2. Effect of the curing time on formaldehyde emission

**3.2** Effect of subsequent thermal treatment

The effect of subsequent thermal treatment was tested on finished sheets which were taken from a production cycle without extended curing time. Figure 3 shows the effect of the thermal treatment on formaldehyde emission at a temperature of 80 °C and 120 °C, respectively, each after 72 hours. This method, too, showed that formaldehyde emission was significantly reduced to approx. 55% and 8%, respectively.

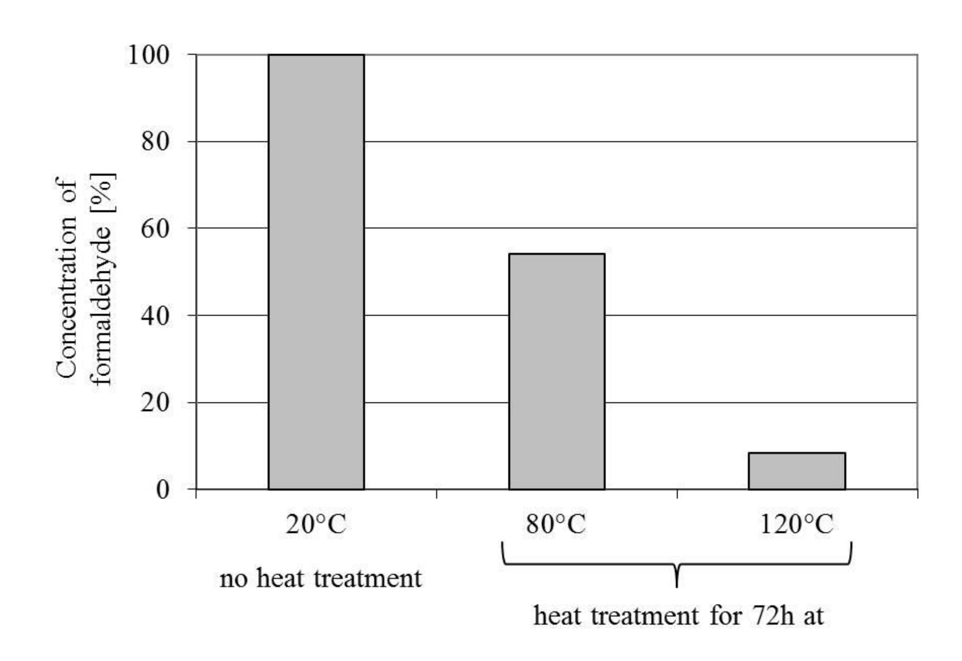



Fig. 3. Effect of subsequent thermal treatment on formaldehyde emission

## 4 DEVELOPMENT OF FORMALDEHYDE-FREE VARNISH PRODUCTS

A long-term solution to the formaldehyde problem can only be the use of alternative formaldehyde-free varnish products, both with regard to industrial safety legislation and under economic aspects. In the past few years, varnish manufacturers, steel producers and punching shops as well as plant manufacturers made intensive efforts to reach such a solution. Since they had to fulfill various general conditions, they suffered multiple setbacks during the development of new products. For example, the varnish has to cure on a new chemical base and meet the same requirements as conventional products as regards its insulation properties, its adhesive strength and its thermal resistance. This also applies to its processability in steel producing facilities (pre-varnishing) and punching shops (post-varnishing).

Table 1 shows examples of examination results from alternative varnishing systems which the varnish manufacturers developed in the past few years and which were characterized in cooperation with plant manufacturers as well as steel producers and punching shops.

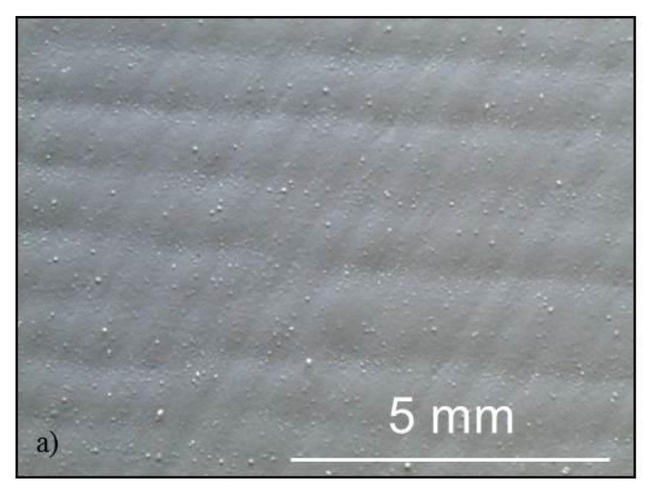
Table 1: TEST RESULTS OF ALTERNATIVE FORMALDEHYDE-FREE VARNISHING SYSTEMS PRODUCED BY VARIOUS VARNISH MANUFACTURERS

| Phase 1: Fundamental Features | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Coating property | Measuring method | reference | varnish 1 | varnish 2 | varnish 3 | varnish 4 |
| 1.1 | curing | wipe test (alcohol) | 🙂 | 🙂 | 🙂 | 🙂 | 🙂 |
| 1.2 | coating thickness | magneto-inductive testing (acc. EN ISO 2178) | 🙂 | 🙂 | 🙂 | 🙂 | 🙂 |
| 1.3 | content of formaldehyde | spectrophotometric analysis (following VDA 275) | ☹️ | 🙂 | 🙂 | 🙂 | 🙂 |
| 1.4 | surface roughness | laser scanning | 🙂 | 🙂 | 😐 | 😐 | 😐 |
| 1.5 | adhesion at ambient temperature | cross cutting (acc. EN ISO 2409) | 🙂 | 🙂 | 🙂 | 🙂 | 🙂 |
| | | stud pull test (7mm) (acc. EN ISO 4624) | 🙂 | 🙂 | 🙂 | 🙂 | 🙂 |
| 1.6 | insulation resistance | Franklin test (acc. IEC 60404-11) | 🙂 | 🙂 | 😐 | 🙂 | 🙂 |

| Phase 2: Heat Resistance | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Coating property | Measuring method | reference | varnish 1 | varnish 2 | varnish 3 | varnish 4 |
| 2.1 | shrinkage after temperature load | stack pressure test (following IEC 60404-12) | 🙂 | 😐 | 😐 | 😐 | 😐 |
| 2.2 | adhesion after temperature load | cross cutting (acc. EN ISO 2409) | 🙂 | ☹️ | 🙂 | 🙂 | 🙂 |
| | | stud pull test (7mm) (acc. EN ISO 4624) | 🙂 | 😐 | 🙂 | 🙂 | 🙂 |
| 2.3 | insulation resistance after temp. load | Franklin test (acc. IEC 60404-11) | 🙂 | 🙂 | 😐 | 🙂 | 🙂 |

The test results show that the surface roughness which has a significant effect on the shrinkage behavior of insulated sheet packages presents particular problems in the new varnishing systems. This was observed both in the pre-varnishing process at steel producing facilities and in the post-varnishing process at various punching shops. In addition, some of the process windows during application are significantly smaller compared to conventional varnish products, a fact which results in an increased reject rate in production.

This is illustrated below by means of the varnishing pattern of a new development as compared with a conventional product (figure 4). The result was achieved on a finishing production facility. As can be clearly seen, the new development has a more irregular fir-tree-like structure of the varnishing pattern.



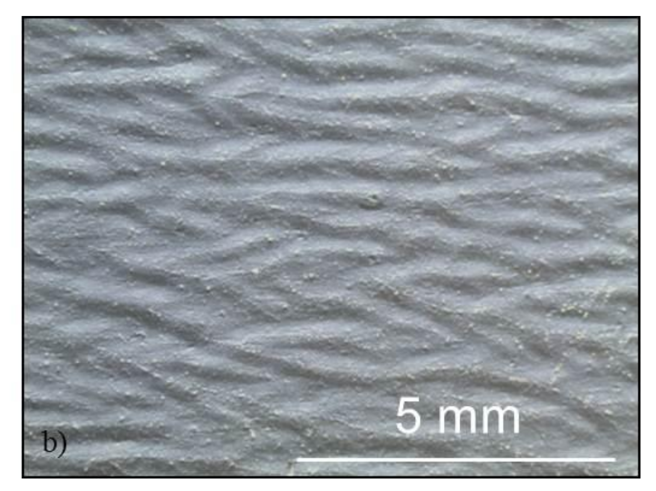
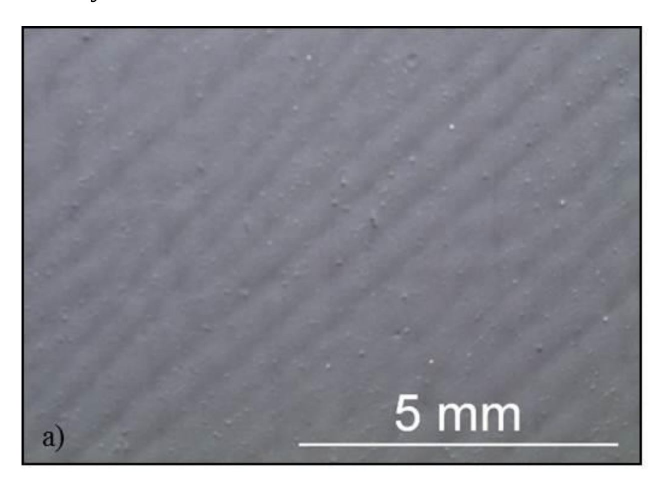




Fig. 4. Varnishing pattern of a conventional varnish as compared with a new product development after the top coat has been applied (light-micrograph)

a) Conventional varnish, containing formaldehyde
b) New development, without formaldehyde

The following figure 5 illustrates the issue of a small process window during application. The picture shows the varnishing pattern of a new varnish development which was achieved on one and the same production facility at different times.



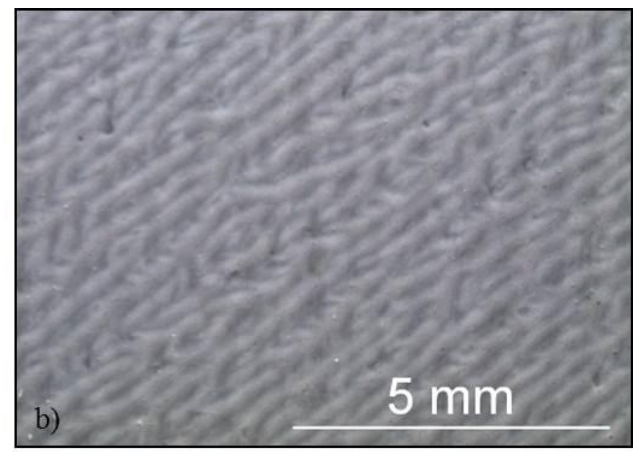




Fig. 5. Comparison of the varnishing pattern of a new development in two different test runs on one and the same production facility

a) Varnishing test 1 in 09/2011
b) Varnishing test 2 in 09/2012

## 5 SUMMARY AND PROSPECTS

This paper showed that the formaldehyde emission of conventional C6 insulation varnishes for stator cores can be reduced by extending the furnace retention time or by subsequent thermal treatment. However, both methods cause considerable additional costs.

A long-term solution can only be reached by substituting existing products, and new products should be characterized chemically such that they cannot release any formaldehyde. To achieve this, varnish

manufacturers, steel producers and punching shops as well as plant manufacturers made various efforts. As experiences have shown, additional development work is required to further improve the properties and processability of these new systems.

The particular objective of future developments must be to improve the surface roughness of the new varnish coats and to expand their process windows towards a more stable application.

## 6 REFERENCES


[1] E.ON conference lecture: “Formaldehyd in Generatoren mit lackisolierten Blechen“, FA-REM Meeting Vienna, 2008

[2] VDA 275: “Formaldehyde release by modified flask / UV Vis Spec method“, 1994